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FLOOD INSURANCE STUDY

74

HAWAII COUNTY, HAWAII

VOLUME 1 OF 4

COMPLETED

ORIGINAL

REVISED:
SEPTEMBER 30, 1988

Federal Emergency Management Agency

COMMUNITY NUMBER - 155166

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study may not contain all data available within the repository. Please contact the community repository for any additional data.

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1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in Hawaii County, Hawaii and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the community that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

This Flood Insurance Study revises and updates a previous Flood Insurance Study for Hawaii County, Hawaii. This information will be used by Hawaii County to update existing floodplain regulations as part of the Regular Phase of the NFIP. The information will also be used by local and regional planners to further promote sound land use and floodplain development.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses for this study were performed by U.S. Army Corps of Engineers (COE), Pacific Ocean Division, for the Federal Emergency Management Agency (FEMA), under InterAgency Agreement No. IAA-H-10-77, Project Order No. 4. The analyses covered work completed in December 1981. Hydrologic and hydraulic analyses for the streams were conducted by M & E Pacific, Inc., under subcontract to the COE, Pacific Ocean Division. These analyses were used to prepare the previous Flood Insurance Study for Hawaii County, Hawaii (Reference 1).

Additional hydrologic and hydraulic analyses for this study were performed by COE, Pacific Ocean Division, for FEMA, under Inter-Agency Agreement No. IAA-84-E-1506, Project Order No. 1. The analyses covered work which was completed in October 1985. For the South Kohala and Hamakua areas, the hydrologic analyses were

carried out by the COE, Pacific Ocean Division and hydraulic analyses were conducted by Wilson Okamoto & Associates, Inc., under subcontract to the COE, Pacific Ocean Division.

The hydrologic and hydraulic analyses for the majority of riverine flooding sources in the North Kona and South Kona areas were performed by the U.S. Department of Agriculture, Soil Conservation Service (SCS). The analyses were taken from the December 1984 North Kona Flood Plain Management study (Reference 2) and the July 1977 South Kona Flood Hazard Analyses report (Reference 3).

1.3 Coordination

Data used in the preparation of this Flood Insurance Study were obtained from the Pacific Ocean Division of the COE, the U.S. Geological Survey (USGS), and the SCS.

A Tsunami Conference was held on February 23, 1977, with coastal engineering and tsunami experts from the University of Hawaii, the Joint Tsunami Research Effort of the National Oceanic and Atmospheric Administration (NOAA), the COE, the Oahu Civil Defense Agency, and the FEMA, to select tsunami study methods to be used in this report.

An initial community coordination meeting was held on August 2, 1983 to determine limits of detailed study areas for revisions and updates to the May 3, 1983 Flood Insurance Study (Reference 1). The meeting was attended by representatives of FEMA, Hawaii County, and the study contractor.

An intermediate/final community coordination meeting was held on October 21, 1985 by FEMA, the community, and the study contractor to discuss the results of the study analyses.

2.0 AREA STUDIED

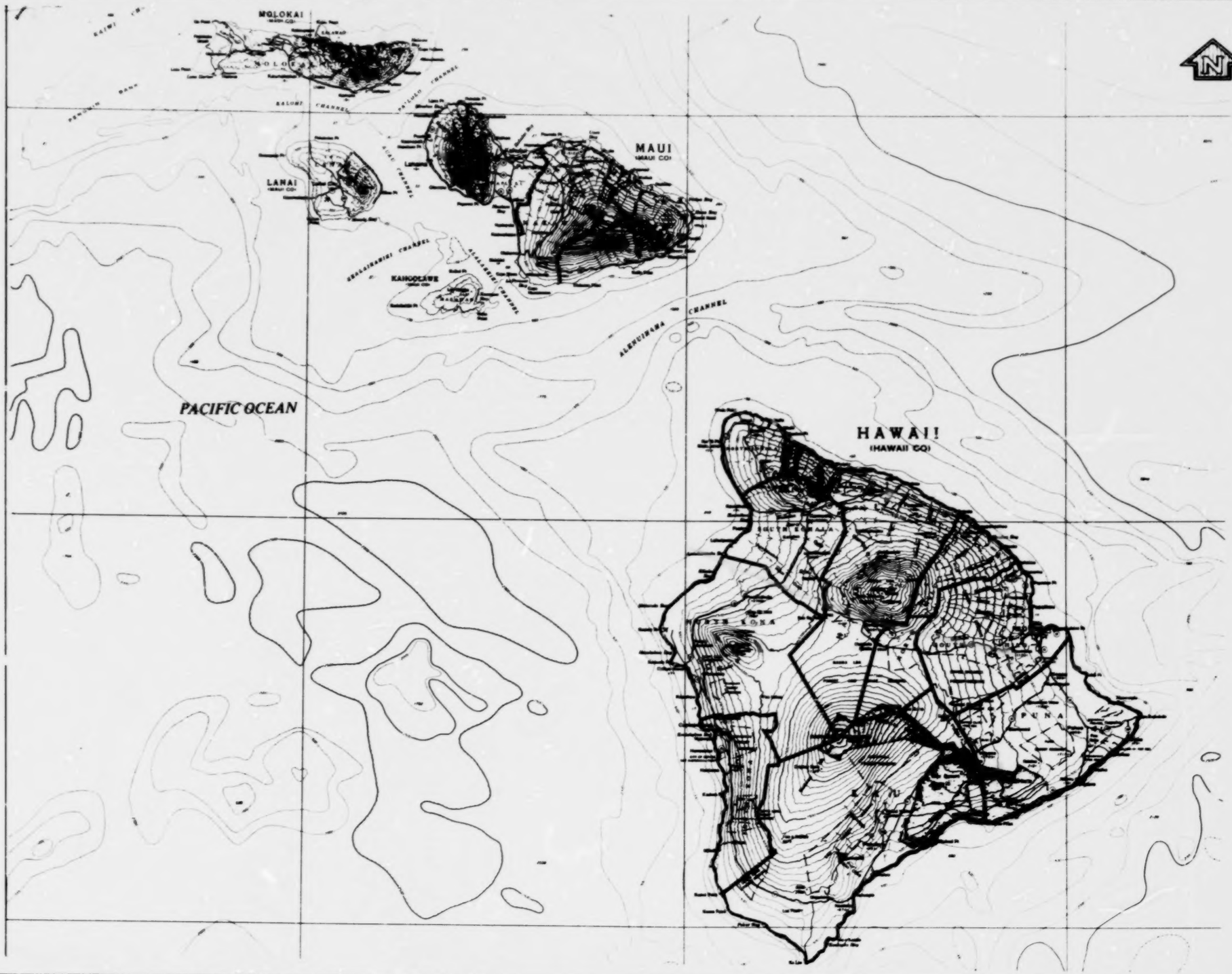
2.1 Scope of Study

This Flood Insurance Study covers Hawaii County, Hawaii. The area of study is shown on the Vicinity Map (Figure 1).

The following streams of the Island of Hawaii were studied in part or as a whole by detailed methods:

SOUTH KOHALA AREA

Lanimaumau Stream
Gulch 4 - Puako
Kamakoa Gulch
Gulch 2 - Hapuna
Gulch 3 - Hapuna
Auwaiakeakua Gulch



APPROXIMATE SCALE

0 3.5 7 10.5 MILES

VICINITY MAP

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HI
(UNINCORPORATED AREAS)

FIGURE 1

BEST COPY AVAILABLE

SOUTH HILO AREA

Waiakea Stream
Waiakea Tributaries 1, 2, and 3
Alenaio Stream
Palai Stream
Four Mile Creek
Shallow flooding tributaries to Palai Stream
(Palai Streams A through F)
Shallow flooding tributaries to Four Mile Creek
(Four Mile Creek Tributaries 1, 2, and 3)

KAU AREA

Ninole Gulch

HAMAKUA AREAS

Honokaa Drainages 1, 2, and 3
Honokaa Drainages A through D

NORTH KONA AREA

Keopu Drainageway
Hienaloli Drainageway
Waiaha Drainageway and tributary
Holualoa Drainageway and tributary
Horseshoe Bend Drainageway
Kaumalumalu Drainageway

SOUTH KONA AREA

South Kona Watercourses Nos. 1, 3, 7, 8, 19, 20, 24, and 25

The entire coastline of Hawaii County, Hawaii was studied for tsunami inundation by detailed methods. The methodology employed to delineate inundation limits of tsunamis of the selected recurrence intervals was agreed upon at the Tsunami Conference held on February 23, 1977.

The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development or proposed construction through October 1991.

The following streams were studied by detailed methods in the SCS North Kona Flood Plain Management study and South Kona Flood Hazard Analyses report (References 2 and 3). These steams are presented as approximate streams in this Flood Insurance Study, based on stream criteria of less than 3 feet average depths or less than 1 square mile drainage areas:

Kainaliu Drainageway
Kawanui-Lehuula Drainageway
Kawanui Drainageway

Lehuula Drainageway
Kaumalumalu Drainageway Tributaries 1, 2, and 3
South Kona Watercourses Nos. 2, 4-6, 9-18, and 21-23

Approximate 100-year flood boundaries along 13 of the streams narrowed to widths of less than 200 feet and have been deleted in their entirety:

Kawanui Drainageway
Kaumaluamlu Drainageway Tributaries 1, 2, and 3
South Kona Watercourses Nos. 4-6, 14-16, 18, 22, and 23

Approximate 100-year flood boundaries at the upstream reaches of the following 7 streams have been deleted where the flooding narrowed to widths of less than 200 feet: South Kona Watercourses Nos. 2, 9, 11-13, 17, and 21.

In addition to the above listed approximate streams, the following streams were studied by approximate methods:

Makahuna Gulch
Makeahua Gulch
Waiulaula Gulch
Gulch near Kawaihae
Waiaha Springs
All gulches between Hawi and Makepala
Puliha Stream
Gulches in Hilo area
Wailuku Stream
Kamuela area gulches - South Kohala
Waikoloa Stream
Kamuela Stream No. 1

Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and Hawaii County.

2.2 Community Description

Hawaii County is comprised entirely of the Island of Hawaii and covers and area of 4,030 square miles, or about 63 percent of the total land areas of the State of Hawaii. The island is 93 miles long, 76 miles wide, and has 318 miles of shoreline. In addition to being the largest of the Hawaiian Islands, the "Big Island" of Hawaii is also geologically the youngest, having been formed from five volcanoes: Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. Of the five volcanoes, only Mauna Loa and Kilauea are still active and intermittent lava flows from these volcanoes continue to contribute to the land mass of the island. The two highest points on the island are the peaks of Mauna Kea and Mauna Loa, at elevations 13,796 feet and 13, 649 feet, respectively. Distribution of the land by elevation shows that five percent of he land is above 10,000 feet, 32 percent is higher than 5,000 feet,

and approximately 80 percent of the land exceeds 1,000 feet. Nearly 76 percent of the land has a slope of less than 10 percent, but much of it only slightly less than 10 percent.

In Hawaii County, streams develop slowly because of the high permeability of water into the soil, especially in areas of recent lava flows. Sheetflow is prevalent due to the slow development of the soil mantle. Perennial streams are located mainly on the northeastern slopes of Manuna Kea and Kohala mountains.

The State of Hawaii is unique among the states in that it has only 2 levels of government: State and County. Hawaii County is subdivided into nine judicial districts: North Kohala, South Kohala, Hamakua, North Kona, South Kona, North Hilo, South Hilo, Puna, and Kau. The population of the island in 1970 was 63,500, and population in 1980 was 92,053 (Reference 4). Future population gains are predicted for South Hilo, South Kohala and North Kona districts.

Hawaii County produces more than half of the beef and diversified agricultural crops grown in the state. Other principal industries are sugarcane, milling, and tourism. The county also claims the only coffee industry in the United States, the largest orchid-growing industries in the world, and rapidly expanding export industry in papayas, macadamia nuts, various tropical flowers and foliage.

The climatic pattern of the island is characterized by a two-season year--a five-month summer and seven-month winter. Extreme diversity in meteorologic conditions exists due to the topographic variations througnout the island. Temperature ranges from 58°F to 90°F at sea level to freezing at the summits of Mauna Kea and Mauna Loa, an average temperature decline of 1°F for every 200- to 300-foot rise in elevation. Annual rainfall varies from from 7 inches at Kawaihae on the leeward coast to 142 inches at Hilo on the windward side, and up to 300 plus inches on the slopes of Mauna Kea.

A detailed description of the areas studied by both detailed and approximate methods follows:

NORTH KOHALA AREA

The District of North Kohala lies on northern end of the Island of Hawaii. North Kohala appears to be geologically the oldest area on the island. The area has an annual rainfall of 30 to 75 inches, and the region from Hawi to Makapala has several deep gulches. Specifically, 15 gulches between Hawi and Makapala were analyzed by approximate methods. With the closing of the sugar mill, the land is used mainly for agricultural purposes.

SOUTH KOHALA AREA

The South Kohala District is noted primarily for livestock and truck farming. With the annual rainfall ranging from 10 to 100 inches, the semi-arid region has little potential for other agriculture use. There is a potential for tourism, which is evident from recently completed resort developments.

Four gulches -- Gulch 1, Waiulaula, Makeahua, and Makahuna--within the Kawaihae area were delineated as approximate-study areas. Gulch 1 and Waiulaula and Makeahua Gulches are similar in relief features, as they are well-defined throughout, with heavy vegetation in the lower reaches and somewhat sparser vegetation in the higher reaches. Makahuna Gulch is well-defined upstream of the Waimea-Kawaihae Road, and downstream sections have been channelized and are clear of vegetation. Runoff from the uninhabited watersheds of Gulch 1, Waiulaula and Makahuna Gulches empties into Kawaihae Bay.

Along the Kawaihae coast of the South Kohala District, gulches studied by detailed methods were Gulch 2-Hapuna, Gulch 3-Hapuna near Hapuna Beach, Kamakoa Gulch, Gulch 4-Puako, and Auwaiakeakua Gulch, in the Puako area. The primary developments in the area are the Puako Beach subdivision and the Waikoloa development by Boise Cascade.

In the Waimea-Kamuela area of the South Kohala District, economic life centers around cattle ranching and truck farming. With a year-round average annual temperature of 50 to 60°F, the growing and grazing industry proceeds continuously. Annual precipitation in Kamuela Town is approximately 40 inches, although only three miles upstream, in the Kohala Mountains, 170 inches per year is the average.

The Waimea Plateau lies between the slopes of Mauna Kea and the Kohala Mountains. Flows from these mountains travel through the plateau via two outlets, Waikoloa and Lanimaumau Streams.

The intermittently flowing Lanimaumau Stream begins in the steep Kohala Mountains. Unlike the Waikoloa, Lanimaumau traverses through flat agricultural farmlands, through some residential development such as Kuhio Village, and finally over rolling meadows to its final destination, a lava tube near the Parker Ranch Race Track. It drains a basin of approximately 39 square miles.

SOUTH HILO AREA

Waiakea Stream, Palai Stream, and Four Mile Creek are three of the five tributaries within the principal Wailoa River system, which drains a total area of about 160 square miles. The other tributaries are Alenaio and Kawili Streams. From the summits of Mauna Loa to the Hilo shore, the contributing drainage areas show increasing development, with the areas below the 1,500 feet elevation primarily developed for commercial, residential, and

agricultural purposes. Alenaio Stream, studied by detailed methods, drains an area of approximately 8.5 square miles. The Waiakea Stream drainage basin is approximately 35.4 square miles in size.

The Palai Stream drainage basin, with drainage area 9.13 square miles, extends about 10.5 miles from Waiakea Pond to the slopes of the Waikea Forest, with elevations ranging from sea level to approximately 1,800 feet. Below the 1,500 feet elevation, the basin is largely developed or planned for commercial, residential or agricultural development. The study includes Palai Stream and its tributaries, extending approximately 5.5 miles upstream from the mouth at Waiakea Pond.

Four Mile Creek, located just south of Palai Stream, drains an area of about 22.6 square miles. The study covers Four Mile Creek for a distance of 2 miles upstream of Kanoelehua Avenue. Located downstream of Kanoelehua Avenue, a recently constructed flood control channel conveys discharge to the Waiakea-Uka Flood Control Basin.

Wailuku River was evaluated by approximate methods. This stream is the largest of the Hilo watercourses with a drainage area of approximately 177.0 square miles.

In addition to the primary streams, other streams in the South Hilo area within the vicinity studied by approximate methods are the Pukihae Stream and two unnamed gulches near Hilo. These well-defined, deep streams are typical of the many streams found between Hilo and Hawi along the Hamakua coast.

KAU AREA

Ninole Gulch, which is situated on the Kau coast near the southern tip of the island, lies within a relatively unpopulated region covered by a fairly recent lava flow devoid of vegetation. While the area is characterized by a lack of well-defined gulches, Ninole is defined by the earthen dikes protecting the Sea Mountain Golf Course and the Aspen Institute. At the mouth of the gulch, the intermittently flowing Ninole Gulch becomes perennial due to the continuously flowing Ninole Springs.

HAMAKUA AREA

The Hamakua district is comprised of several small communities scattered along the coastal belt. Sugarcane cultivation is the major economic industry in the area. Other agricultural activities include taro, truck farm produce, macadamia nuts, and cattle ranching.

Honokaa town, located at the 1,100 feet elevation along the Hamakua coast, is covered in this study. A detail-shallow flooding analysis was conducted for this area which is prone primarily to

sheet flow and shallow flooding. The Honokaa drainage basin covers an area of approximately 2.4 square miles.

NORTH KONA AREA

On the central leeward coast of Hawaii, the North Kona District is defined by relatively recent lava flows and the absence of well-defined drainage channels. Starting from the slopes of Mount Hualalai and Mauna Loa, the vegetation increases with lower elevations, except near the shore which is used for cattle grazing. With an annual rainfall ranging from 15 to 100 inches, the diverse vegetation ranges from none above the 8,500 feet elevation, to sparse between 8,500 and 6,000 feet, to moderately fertile in the forest reserves between 6,000 and 3,500 feet, to fertile in the agricultural zone between 3,500 and 800 feet.

The area consists of a series of narrow, underdeveloped drainageways that flow to the ocean. Seven intermittent drainageways totaling 300 miles in length were identified during the study as having flood hazard potential. They included the Kainaliu, Kawanui/Lehuula, Kaumalumalu, Holualoa/Horseshoe Bend, Waiaha, Hienaloli and Keopu drainageways.

Soils in this area may be classified into three major groups based on the amount of volcanic ash or organic matter covering the basaltic material. These groups are volcanic ash soils, organic soils, and young unweathered lava.

The floodplain areas in this study are composed of urban, agricultural and forest land. In addition, a preliminary survey, shows historical, archaeological, recreational, wetland-and-endangered plant, and animal sites scattered throughout the study area (Reference 2).

SOUTH KONA AREA

Located on the western slopes of Mauna Loa, this study area consists of a series of narrow drainage areas with underdeveloped watercourses that drain into the Pacific Ocean. Twenty-five such watercourses were identified as having flood hazard potential.

All watercourses within the study area are intermittent. Much of the floodflows percolate into lava formations and reach the ocean as surface flow only after periods of intense and sustained rainfall. The drainage area above 6,000 feet elevation appears not to contribute to surface runoff. This area includes nearly barren lava, volcanic ash, pumice, and cinders.

The mean annual rainfall ranges from approximately 40 inches at sea level to about 80 inches at 3,000 feet elevation. Above the 3,000 feet level, rainfall gradually decreases from 80 inches to about 15 inches near the summit of Mauna Loa.

Soils in the drainage area are dominated by well-drained, very shallow soils formed from organic matter over pahoehoe lava or fragmental aa lava. The thickness of the organic layer increases with increasing rainfall but is generally less than 10 inches. The vegetation consists of ohia, tree fern, koa, guava, christmas berry, parture grasses, coffee and macadamia nuts (Reference 3).

2.3 Principal Flood Problems

The island of Hawaii is subject to flooding from both stream overflow and tsunamis. In some areas along the coast, both types of flooding may occur. The major flood hazard on Hawaii is tsunami inundation. Tsunamis, which are a series of waves generated by submarine, earth movements, travel at high velocities and have had a devastating effect on the developed areas of Hawaii. The sources for these tsunamis are varied and located in North and South America, the Aleutian Islands, Japan, Kamchatka, the islands lying between the Philippines and Samoa, and even in Hawaii. The City of Hilo has been most severely damaged. Based on 1970 figures, Hilo had suffered losses of $62 million over the past 50 years.

While the specific cause for tsunamis can be attributed solely to the faulting of the ocean floor, the cause of flooding due to stream overflow is not limited to a single factor. Possible flood causes include: debris-clogged streams, flash floods, undefined streamflow patterns, isolated depressions in topography, inadequate drainage facilities, and changed drainage conditions due to development.

The rainfall related flood problems of the detailed and approximate study areas are further discussed by flooding source in the following paragraphs.

NORTH KOHALA AREA

The majority of the 15 gulches within the district are heavily vegetated and well-defined at the lower reaches below the Mahukona-Niulii Road. Above the Mahukona-Niulii Road, the gulches are less defined and less densely vegetated. No major flood problems have been identified, and only minimal damage by sheet runoff has been reported in the Hawi and Kapaau areas.

SOUTH KOHALA AREA

For the approximate study areas of Gulch 1, Makeahua and Makahuna Gulches, no major flood conditions are identified. The coastal areas of the South Kohala District from Kawaihae to Puako are subject to shallow flooding. Specifically, Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch and Auwaiakeakua Gulch usually contain the runoff in the higher segments, but become undefined in the lower regions, causing shallow flooding conditions.

In the Waimea region, the rock outcrops and sharp bends of Waikoloa Stream form restrictive sections which enhance flooding. This condition is most evident in the area immediately downstream of Lindsey Street bridge. Here, the floodwaters of Waikola Stream tend to back up and overflow due to the exaggerated, acute, channel bends and the thick foliage immediately downstream of the bridge. During flood stages, water overtops the bridge and floods the vicinity. Further downstream, however, the entire flow is maintained within the Waikoloa Stream floodplain.

In the past, overflow of Lanimaumau Stream has caused severe economic damage. The storm of August 1958, for example, resulted in damage to truck farmcrops from flood waters as deep as 2.5 feet. Total estimated damage was $186,380. Recently, this flood damage potential has been reduced by the construction of the Puukapu Channel (Reference 1).

SOUTH HILO AREA

Alenaio Stream-flows indicate a floodprone situation. On July 25, 1966, the overflow points were the Kapiolani Street bridge, Ululani Street bridge, the Kinoole Street bridge, the Kilauea Street bridge, and Waialama Canal. The diversion dam above Kinoole Street (Ponahawi box drain) clogged, and the ensuing full flow along the stream resulted in the complete collapse of homes in the vicinity of Osorio Lane. The July 25, 1966 storm precipitation has been estimated as having a 50-year recurrence interval. Flow impediments increased the magnitude of flooding caused by the event. Conditions that abet flooding in the area are the blockage of the streambed with existing pipe crossings and the heavy growth of grass on the streambed and banks.

Intense rainfall during the period February 18-25, 1979 resulted in extensive flooding, especially in the low lying areas of Hilo. More than 100 homes along the Palai/Four Mile Creek drainageway were inundated forcing a general evacuation of the area. Stream overflow onto Kanoelehua Avenue caused disruption of traffic.

The aforementioned storm events represent a mere sample of the extreme nature of flooding experienced in the area. Principal flood problems within the study limits include stream overflow along drainageways and surface runoff resulting from inadequate interior drainage.

KAU AREA

The Kau district has been subjected to severe floods in Naalehu, Waiohinu, and Pahala, but improvements in these locations have lessened the flood hazard. Overall, the flood threat has been reduced in the desert region of the island, especially at Ninole Gulch, where protective earthen dikes were built to minimize flooding.

HAMAKUA AREA

The town of Honokaa, located in the northern Hamakua region, is subject to sheet flow flood problems, due to the lack of well developed stream channels in the area.

Notable floods in the area include that of April 1961 and November 1979. The rare flood of April 2-3, 1979 was one of flash nature, combining the elements of intense rainfall and steep sloped mountains to produce rapidly concentrating runoff. Damages to sugar, farming, cattle ranching industries were reported. During this storm, nearly all culverts were overtopped, including those which cross the interstate defense highway, which were designed to handle 50-year discharges, according to Hawaii State standards. At several locations, channel cross sections upstream of culverts contained areas twice as large or larger as that of the culvert. Some county bridges were overtopped as well.

Thunderstorm rain over Mauna Kea and the Kohala Mountains during the November 16-19, 1979 storm caused severe damage to the east Hawaii area, including the town of Honokaa. Sugarcane and diversified agriculture in the area suffered the heaviest loss. Roads, bridges, water supply pipes, and other public works were damaged by floodwaters as well. As an indication of the flood magnitude, the neighboring Ahualoa Stream was recorded at 4,100 cubic feet per second (cfs) on November 17-18, 1979. This station has been in operation since 1963 and the previous known maximum flow was 760 cfs on January 14, 1979.

NORTH KONA AREA

Historically, several flood problems have been noted within the North Kona District. Floods in Kailua-Kona result primarily from Waiaha Springs. Sheet runoff from the steep slopes of the Holualoa Watershed has also been known to cause some flood problems. Records indicate that Kainaliu was also subject to flood hazards, as the flood of April 29, 1963, caused damages amounting to $50,000.

Storms in the area occur in a few drainageways and not over the whole study area resulting in storm damages being concentrated in specific drainageways. Since 1955, there have been 22 storms that have damaged the area. The most recent storms occurred in October 1968, October 1974, and February 1982.

Damages from the October 1968 flood were estimated at about $95,000, and were centered in the Holualoa/Horseshoe Bend and Kaumalumalu drainageways. Public facilities including county roads, bridges and domestic water systems suffered damages in excess of $400,000 from floodwater, debris and erosion. Kuakini Highway and Alii Drive were washed out in several locations causing disruption to traffic. A 100-foot by 40-foot deep section of Mamalahoa Highway at Holualoa was ripped out by the raging floodwaters. Floodwaters also damaged about 40 residences along

Mamalahoa Highway and Alii Drive. The USGS Waiaha Stream at Luawai Stream gage (No. 16759300) measured a peak discharge of 3,100 cfs which approximates a 25-year storm event.

The October 1974 storm was centered over the area between Holualoa and Kainaliu with most of the damages occurring in Kainaliu town and the Holualoa/Horseshoe Bend Drainageway below Kuakini Highway. This storm was of short duration and the rain gage at Kainaliu (No. 73.2) measured 3.77 inches in a 2 hour period, which approaches a 100-year event.

The February 1982 storm was centered over the North Kona area from Keopu to Kaumalumalu drainageways. The Big Island Civil Defense Authority estimated damages in excess of $3 million. The Keopu drainageways suffered the most damages with over $1 million losses to roads and residences in the Keopu Heights Subdivision and to commercial buildings in Kailua town. The Waiaha Stream USGS gage at Luawai (No. 16759300) measured a peak discharge of 3,500 cfs or about a 25-year frequency storm. Rain gages at Lanihau (No. 68.2) and Holualoa (No. 69.16) also had rainfall amounts that approximated a 25-year frequency storm (Reference 2).

SOUTH KONA AREA

Flooding problems have been largely due to localized high intensity rainfall from about 1,000 to 5,000 feet elevation. Such storms can occur anywhere along the mountain slopes of South Kona. In addition to these localized storms, a few general storms have occurred covering the whole width of the study area.According to storm damage reports by SCS (Reference 3), there have been 17 damaging floods since 1956. Other floods have occurred before this date but no detailed accounts are available. Accurate data on rainfall and flood flows are nonexistent but general accounts are available from storm damage reports.

On March 31, 1956, rainfall was estimated at about 8 to 12 inches with the highest intensity occurring from 6 to 9 p.m. This rainfall amount was greater than the 100-year, 24-hour frequency (Reference 3). On April 29, 1963, approximately 4 inches of rain fell within 2 hours. Total rainfall amount was equivalent to the 100-year, 24-hour frequency storm.

On November 20, 1967, heavy rains fell at elevations of approximately 4,000 feet in the Honaunau area which generated stream flow causing serious damage to the Honaunau Post Office building, farm roads, and buildings surrounding the Post Office. The rain began at 2 p.m. and subsided at 4:35 p.m. During this period, 4 inches of rainfall was measured. This rainfall amount was equivalent to the 100-year, 24-hour frequency storm. On May 26, 1976, rainfall began at about 3 p.m. and continued to about 7 p.m. The only recording rain gage (USGS) in the area was not functioning properly but estimated rainfall at the Honaunau Post Office for the 4-hour duration was about 5 inches. This rainfall amount had a recurrence interval greater than once in 100-years.

2.4 Flood Protection Measures

Hawaii County now exercises floodplain regulation, which gives the county authority to examine all construction permits for possible flood hazard and either accept or reject the permit or require adequate flood-proofing.

A tsunami warning system has been developed for the entire State of Hawaii. This warning system is designed to provide sufficient time for evacuation from tsunami danger zones.

The county of Hawaii has constructed, or plans to construct, flood control improvements, with state and federal governmental assistance. A description of these joint efforts follows:

NORTH KOHALA AREA

Consistent with the lack of flood problems in the North Kohala District, there are no existing or planned flood control projects in the region.

SOUTH KOHALA AREA

For the Kawaihae area, no flood control projects are planned, as the flood potential is minimal. Further, along the Kawaihae to Kailua-Kona coast, the Hapuna Beach-Puako gulches (Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch, and Auwaiakeakua Gulch) have not been improved for flood control purposes. Except for small drainage ditches along the coastal areas below Kamakoa Gulch, there are no project flood protection alterations. For the Puukapu watershed in the Kamuela area, a retarding dam and diversion channel were constructed through a joint undertaking of Hawaii County, the State of Hawaii, and the SCS. The Puukapu Channel was designed to divert 100-year frequency storm runoff from the Lanimaumau Stream to Paiakuli Reservoir. The diversion channel has a capacity of 1,450 cfs.

SOUTH HILO AREA

The completion of the Waiola River Flood Control Project in August 1965 by the COE upgraded the capacity of Waiakea Stream to transmit the 100-year flood. Within a year after completion, the 50-year flow of the July 25, 1966, storm tested the flood protection channel, and no flood damage occurred in the Waiakea Stream section of Hilo.

In 1974, the incremental construction on the Waiakea-Uka Flood Water Disposal Project, was initiated by local interests. Phase I of the project, completed in 1976, consists of excavation of 7,600 feet of planned 9,600 feet open channel, construction of two bridges across the channel and partial construction of the detention basin. Phase II, which would complete the project, includes: 1) Palai culvert - to divert a portion of the flow from

Palai Stream into Four Mile Creek; 2) open channel - the remaining 2,000 feet of open channel (unlined, trapezoidal); 3) detention basin - completion of the basin to allow storage and dissipation of floodwaters and unlined spillway to discharge flow in excess of basin capacity. Phase II construction has not been completed.

It is expected that the Alenaio Stream flooding problem will be lessened in the upper region by the Wailuku-Alenaio Watershed Project, initiated by the SCS. The objective of the project is to collect streamflow from the watershed above Alenaio and transfer the flow to Waipahoehoe and Kaluiiki Streams, tributaries to Alenaio stream. This project also entails diverting flow from the Piihonua watershed to Wailuku River above Akolea Road. While the project alone does not alleviate flood hazard in Lower Alenaio below Komohana Road, residents in Kaumana, Chongmanville, Piihonua, and Ainako will be benefit greatly.

Hawaii County has completed the Manuelele diversion project in the Ainako area, which drains Kaumana Terrace waters into the Wailuku River. County projects in the planning stages include both channel work on Alenaio Stream between Komohana Road and Kapiolani Street, and a diversion parallel to Komohana Road that would intercept and transfer upstream Alenaio flow to Wailuku river. While a timetable for these projects has not been set, the installation of either project would reduce flood damage in downtown Hilo.

Kau Area

In Pahala, the flood problem of excessive sheet runoff has been alleviated with construction of flood diversion structures near the sugar plantation. For Naalehu Village, a debris basin and floodwater channel were constructed in 1965, with additional improvements and modifications completed 1969. The SCS designed the 100-year frequency flood protection project under the authority of the Watershed Protection and Flood Prevention Act. These improvements at Pahala an Naalehu have served to minimize the flood hazard in the Kau District.

Hamakua Area

At present, no major flood control projects exist in the town of Honokaa area.

North Kona Area

Presently, flood control projects are planned stages for areas near Disappearing Sands Beach, Holualoa Bay, the resort developments, and inland to the Alii Kai Subdivision. Flood control measures include a channel system, siltation and catchment basins, bridge crossings, and streambed deepening. These measures would be designed for a 100-year frequency flood.

The previously serious flooding conditions in the Kailua and Kainaliu areas have been alleviated with the construction of flood

control projects, mainly Keopu Channel and Kainaliu Diversion Flood Control System. Both projects were designed to accomodate a 100-year frequency flood. The Keopu Channel has a capacity to divert 3,200 cfs, and the four Kainaliu diversion structures were designed to transmit 100 cfs, 130 cfs, 300 cfs, and 175 cfs, respectively.

There are two existing dams in the area, both of which are adjusted to the Waiaha Drainageway and are presently being used for livestock purposes. The Luawai Reservoir is at elevation 2,500 feet and the other unnamed dam at elevation 3,200 feet. The Lauawai Reservoir has a storage capacity of about 3 million gallons while the unnamed reservoir has less capacity. Both of these reservoirs have earth embankments of less than 5 feet.

SOUTH KONA AREA

A study of the South Kona areas was conducted by the SCS at the request of the County of Hawaii (Reference 3). Based on this study, the SCS has recommended structural and nonstructural flood protection measures for the county to implement. Nonstructural measures include:

1.) Preserving the conservation and agricultural land use areas above Mamalahoe Highway.
2.) Establishing and maintaining appropriate vegetative cover on sediment-and debris-producing areas.

3.) Enforcing county grading ordinances.

4.) Implementing land use zoning to restrict future development within identified floodplain, or requiring proper structural design to prevent floodwater damages from the 100-year event.

Recommended structural measures are:

1) Relocating or floodproofing buildings which are flood prone.

2) Improving road culverts and bridges.

3) Developing a diversion system using lava tubes.

4) Requiring all structural or land improvements to compensate for increased runoff.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10, 2, 1 and 0.2 percent chance,

respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied in detail affecting the community.

The multiple regression technique was used to develop the relationship between pertinent characteristics of the station flood-frequency curves and basin and climatological characteristics. The station flood-frequency curves were determined using the procedures outlined in the Water Resources Council Bulletin No. 17 (Reference 5). A generalized skew coefficient of -0.05 was used for all station frequency curves.

From the station flood-frequency curves, discharges at selected recurrence intervals were determined. Each set of discharges was then correlated to various basin and climatological characteristics using a regression equation of the following form:

$$Q_T = aX_1\ ^{b_1}\ ^{b_2}\ ^{b_n},\ X_2\ \ldots^{x_n}$$

where Q_T is the discharge corresponding to recurrence intervals of T years,

$a, b_1, b_2, \ldots b_n$ are constants, and

$X_1, X_1, \ldots X_n$ are basin and climatological characteristics.

Regression constants were computed by the method of least squares. Statistical tests were made to eliminate those basin and climatological characteristics that had little or no significance. From the final equations for discharges corresponding to selected recurrence intervals, a flood-frequency curve can be constructed for any site, once the values of the significant characteristics are determined

An examination of all gaging station records yielded 35 stations with adequate records for the flood-frequency analysis. Station flood-frequency curves were computed and discharges for the selected recurrence intervals were determined for the 35 stations.

A multiple regression analysis was conducted by using the records for the entire island, and also by separating the records into the windward and leeward stations. The best relationships in terms of standard error and multiple correlation were found by using the windward and leeward division, as shown in Figure 2.

The most significant basin and climatological characteristics for the windward area of Hawaii were found to be drainage area (DA) and mean annual precipitation (PA), and those for the leeward area were drainage area (DA) and the 2-year 24 hour precipitation (P24-2).

The regression equations for the windward grouping for the 10-, 50-, 100-, and 500-year floods were:

$$Q_{10} = 313\ (DA)^{0.67}\ (PA)^{1.27}$$

$$Q_{50} = 641\ (DA)^{0.64}\ (PA)^{0.70}$$

$$Q_{100} = 822\ (DA)^{0.64}\ (PA)^{0.50}$$

$$Q_{500} = 1361\ (DA)^{0.62}\ (PA)^{0.10}$$

The regression equations for the leeward grouping were:

$$Q_{10} = 8.7\ (DA)^{0.55}\ (P24\text{-}2)^{2.62}$$

$$Q_{50} = 24.1\ (DA)^{0.72}\ (P24\text{-}2)^{2.35}$$

$$Q_{100} = 34.3\ (DA)^{0.77}\ (P24\text{-}2)^{2.26}$$

$$Q_{500} = 62.1\ (DA)^{0.88}\ (P24\text{-}2)^{2.14}$$

Where:

(DA) = Drainage Area

(PA) = Mean Annual Precipitation in hundreds of inches

(P24-2) = 2-year 24-hour precipitation in inches

For Alenaio Stream, a regional analysis relating discharge to drainage area was used in lieu of the multiple regression technique. Data from twelve stream gaging stations near Alenaio Stream was used. Individual discharge frequency curves for these stations were calculated following procedures based on the Water Reservoirs Council Bulletin No. 17 (Reference 5). The 50-, 10-, 2-, and 1-percent discharges were plotted against their respective

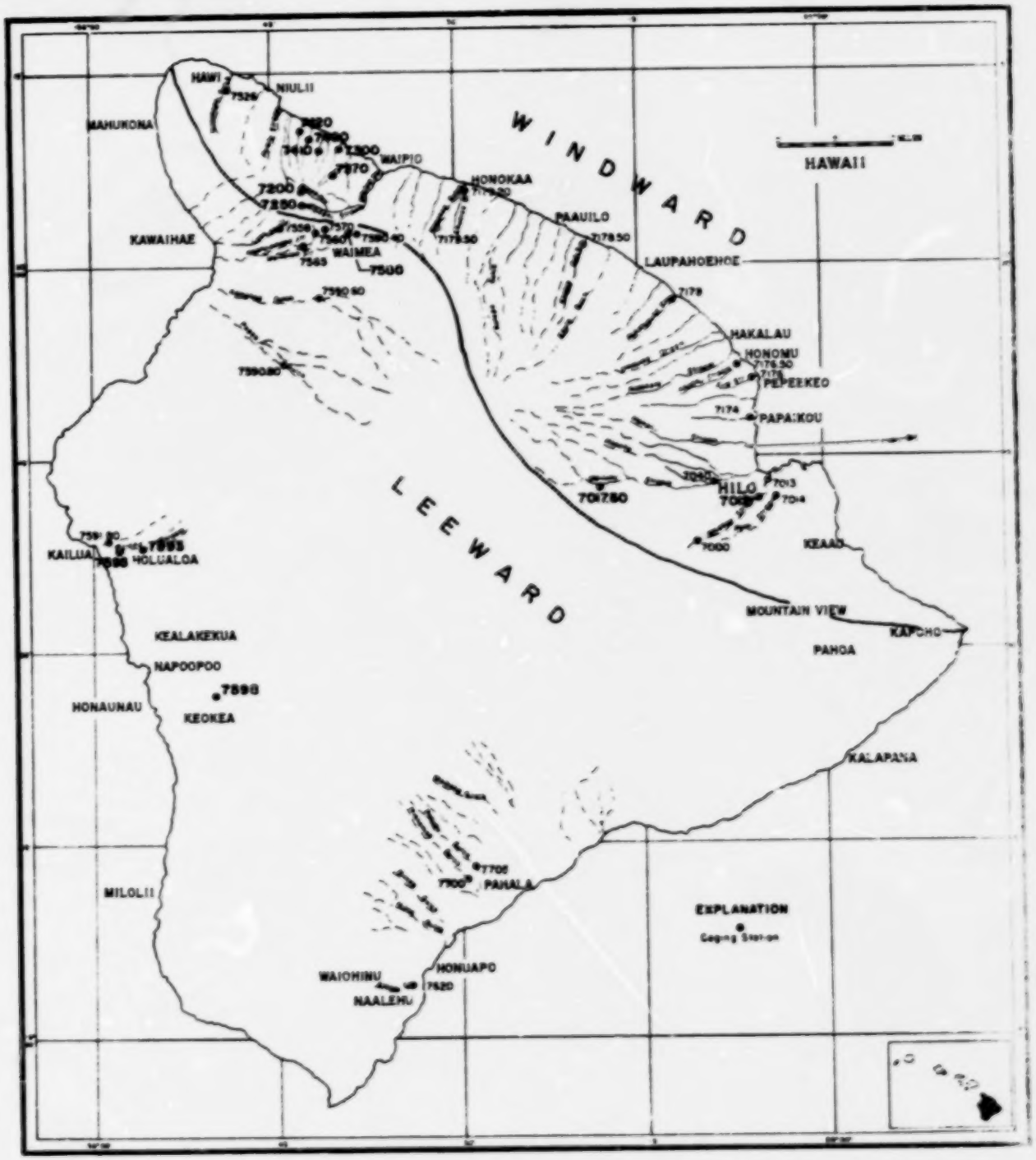


Figure 2 - Divison of Stations, Windward and Leeward Groups

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areas to determine regional discharge drainage area relationships. From these curves, discharges for Alenaio Stream were determined.

For Waiakea Stream, gage data from Stations 7000, 7012, and 7013 along the stream were used to determine peak discharges, in lieu of the multiple regression technique. Discharge frequency curves were calculated following procedures based on the Water Resources Council Bulletin No. 17 (Reference 5).

The hydrologic analyses for the North Kona streams studied by detailed methods were developed in the December 1984 North Kona Flood Plain Management study (Reference 2). The hydrologic analyses were based on SCS methodology found in Section 4, SCS National Engineering Handbook (Reference 6). A computer program (Technical Release No. 20) was used to compute peak discharges at all cross sections for the 10-year, 50-year, 100-year, and 500-year frequency storms (Reference 7).

Runoff curve numbers used in the SCS hydrologic method were estimated from soils and land use information and compared with previous hydrologic studies done in the area. Soil information was obtained from the 1973 Soil Survey of the Island of Hawaii, State of Hawaii, published by the SCS in coorporation with the University of Hawaii Agricultural Experiment Station (Reference 8). Rainfall data was obtained room the National Weather Service, Technical Paper No. 43 (Reference 9).

There are three active stream gages in the North Kona area: right branch Waiaha Drainageway near Holualoa (No. 16759200), Waiaha drainageway at Luawai (No. 16759300), and Keopu Drainageway near Kailu (NO. 16759180). The former two are continuous recording gages with a period of record from 1961 to 1980; the latter is a crest gage station with a record period from 1965 to 1980. Frequency-discharge curves based on the Water Resources Council guidelines (Reference 5) for all three gages were compared to frequency-discharge curves as derived from the computer output and curve numbers were adjusted so that peak discharges were compatible with Water Reservoirs Council estimates.

The hydrologic analyses for the South Kona streams studied by detailed methods were determined in the July 1977 South Kona Flood Hazard Analyses report (Reference 3). No basic data on rainfall and runoff were available that could be used for quantitative analyses. These are seven daily raingages but all are located outside of the heavy rainfall zone. Stream discharge measurements are nonexistent. The high water marks observed in some watercourses cannot be relied upon because of large sediment and debris movement during flood flows. The USGS maintains recording gages and stream gages on Watercourse 20, but data from these gages are very sparse. During the larger storms, one instrument or both became inoperative or was damaged.

Peak flows in the South Kona streams were computed using the procedures described in Section 4, SCS National Engineering

Handbook (Reference 6). Runoff curve numbers were estimated qualitatively from field observations, soils information, and an infiltration study by the U.S. Forest Service in the Kona area. Rainfall data were obtained from the National Weather Service, Technical Paper No. 43 (Reference 9). Soil information was obtained from the 1973 Soil Survey of the Island of Hawaii, State of Hawaii (Reference 8). Because the watercourses are poorly defined, special effort was made to locate problem areas by interviewing local residents and studying storm damage reports made by personnel of Bishop Estate and SCS.

Peak discharge-drainage area relationships for streams studied by detailed methods are shown in Table 1.

TABLE 1. SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (square miles)	Peak Discharge (cubic feet per second) 10-Year	50-Year	100-Year	500-Year
Lanimaumau Stream					
At Mamalahoa Highway	0.87	890	1,520	1,820	2,700
Gulch No. 2 - Hapuna					
At Confluence with Hapuna Bay	10.92	420	1,300	1,950	4,400
Gulch No. 2 - Hapuna					
At Confluence with Waialae Bay	4.05	210	570	800	1,650
Kamakoa Gulch					
At Mouth	91.18	1,850	7,900	13,000	38,000
Gulch No. 4 - Pauako					
At Mouth	3.54	215	565	790	1,650
Auwaiakeakua Gulch					
At Mouth	68.93	1,550	6,400	10,500	29,000
Alenaio Stream					
At Confluence With Waiola River	8.53	2,820	4,900	5,950	8,900
Waiakea Stream					
1000 Feet Upstream of Lanikula Street	35.4	1,620	2,850	3,570	5,600
At Kupulau Street	33.4	1,500	2,620	3,280	5,160
Waiakea Tributary No. 1					
At Confluence With Waiakea Stream	0.11	[1]	[1]	220	[1]
At Kawailani Street	0.01	[1]	[1]	50	[1]

TABLE 1. SUMMARY OF DISCHARGES (con't)

Waikea Tributary No. 2					
At Confluence With Waiakea Stream	0.42	___1	___1	525	___1
At Kawailani Street	0.33	___1	___1	450	___1

1 Discharge not determined

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

The hydraulic analyses for the North Kona streams studied by detailed methods were determined in the December 1984 North Kona Flood Plain Management study (Reference 2).

Channel cross section data taken from the topographic maps (Reference 10) and surveyed cross sections were compiled for input into the COE HEC-2 water-surface profile computer program (Reference 11). Output data from this program were used to develop elevation-discharge and top width-discharge rating curves for each cross section. The elevation-discharge rating curves were used with the peak discharge information from the TR-20 output (Reference 7) to obtain water-surface elevations at each cross section for the 10-, 50-, 100-, and 500-year events. These elevations were adjusted to conform to known high water marks from the February 1983 storm.

The hydraulic analyses for the South Kona streams studied by detailed methods were determined in the July 1977 South Kona Flood Hazard analyses report (Reference 3).

Several watercourses experience high channel losses as a result of seepage and natural storage. The natural storage is composed of both surface depressions and subsurface openings such as lava tubes. Seepage losses are the result of porous lava formations beneath the streambeds. These losses, seepage and storage, were neglected in the computation of the water-surface profiles because of insufficient data for accurate estimates. Interviews with the local people also indicated that the lava tubes and streambeds are being filled by an accumulation of debris and sediment.

Procedures used are described in Section, SCS National Engineering Handbook and Technical Release 61 (Reference 12 and 13). The cross section data taken from the topographic maps (Reference 14) were plotted and compiled for input into the SCS Water-surface Profile Computer Program WSP2 (Reference 13). The output data from the WSP2 computer program developed rating tables (elevation-discharge) for each cross section. These rating tables were used with the peak flow frequency information from the TR-20 program run to

obtain water-surface elevations at each cross section for the 10-, 50-, 100-, and 500-year frequency flood events.

For the remaining streams studied by detailed methods, the COE HEC-2 step-backwater program was used in the computation of water-surface elevations for selected recurrence intervals (Reference 11). Parameters for HEC-2, such as channel roughness coefficients, were obtained from field reconnaissance and photographs of individual detailed-study areas. An effort was made to utilize channel roughness coefficients established by the USGS for similar conditions, by viewing their stereo-photo records. Cross sections used in the backwater analyses were derived from both topographic maps furnished by the COE and supplemental field surveys. Information on bridges and culverts was obtained from the Sate of Hawaii Department of Transportation, and verified by field inspections.

For most streams, the starting water-surface elevation was assumed at normal depth due to the relatively steep slopes that produced supercritical flow. Control sections such as bridges and culverts, which reduced channel slope, and other restrictions were analyzed for backwater profile effects.

For most of the remaining flooding sources, aerial survey maps at a scale of 1:4800, contour interval 5 and 10 feet, were provided by the COE (Reference 15). For selected areas, maps at a scale of 1:2400, with 5-foot contour intervals, were available (Reference 16). Maps for portions of the coastline of Hawaii County were developed from USGS topographic maps, at a scale of 1:24,000 enlarged to 1:12,000, contour interval 20 feet (Reference 17). For portions of the Hilo area, aerial survey maps at a scale of 1:1200 were used (Reference 18).

The following is a description of the sources and bases of data used in the detailed studies of the watercourses:

SOUTH KOHALA AREA

Along the Kawaihae to Kalilua-Kona coast of Hawaii, the hydraulic basis for Gulch 2-Hapuna, Gulch 3-Hapuna, Gulch 4-Puako, Kamakoa Gulch, and Auwaiakeakua Gulch were obtained from field surveys that supplemented topographic maps furnished by the COE Reference 15). Roughness facotrs were based on field observations.

In the Waimea study area, the hydraulic computations for the Lanimaumau Stream were based on topographic information furnished by the COE and on field surveys for cross sectional and roughness factors. The Puukapu Watershed Plan of the SCS (Reference 19) provided data on the Paiakuli diversion channel. Channel improvements for Kuhio Village II (Reference 20) were also incorporated.

SOUTH HILO AREA

The downstream detailed study of Hilo's Waiakea Stream was based on data from several sources. After field verification of the cross sectional data, the "as-built" ground data from construction plans of the Waiola Stream and tributaries Flood control Project completed in 1965 (Reference 21) were adopted for study usage. These plans, together with the Lanikaula Street Extension Plans (Reference 22), field determination of roughness coefficients, hydrologic data and topographic maps provided by the COE, formed the basis for the Waiakea Stream study.

The upstream detailed study of Waiakea Stream was based on data obtained from several sources. Plans of the Waiakea Stream improvements between Golden Shower Tree Estates and Kawailani Street bridge (Reference 23) were utilized. These flood control measures have been recently constructed. The Waiakea Stream improvements between Kawailani and Komohana bridges (Reference 24) were incorporated into the study. Flood protection systems located at Kupulau Road (Reference 25), Lehua Heights Subdivision (Reference 26) and Golden Show Tree Estates (Reference 27) were also adopted for use. The plans, together with field investigations and hydrologic data and topographic maps provided by the COE (Reference 28), were the basis of data used or Waiakea Stream.

For Alenaio Stream, field surveys were conducted to obtain data on bridge geometry, roughness coefficients, and cross section data. The field data were supplemented with data from prior reports, including Hilo Drainage and Flood Control by Wilson, Okamoto, & Associates (Reference 29) and Alenaio Stream Flood Control Improvements, Plan and Profiles, by Neighbor Island consultants (Reference 30). Additional topographic maps and hydrologic information were obtained from the COE (Reference 18).

For Palai Stream and tributaries data on bridge geometry, roughness coefficients and cross section characteristics were obtained through field surveys. The Flood Plain Management Planning Assistance Report for Palai Stream and Four Mile Creek, prepared by the COE in 1981 (Reference 31) was used to supplement field data. Plans for the widening of Palai Street bridges (Reference 32) were also incorporated in the study. The topographic maps used in the study were furnished by the COE (Reference 28).

Cross sections used in the backwater analyses of Four Mile Creek and tributaries were derived from COE topographic maps (Reference 28) and field surveys. Bridge and culvert information was obtained through field investigation.

KAU AREA

In computing the flood hazards for the Honokaa town area, the detailed study was based on channel roughness factors determined by field inspections and on basic topographic maps provided by the COE, (Referene 15), supplemented by field-surveyed cross sections.

HAMAKUA AREA

In computing the flood hazards for the Honokaa town area, the detailed study was based on basic topographic maps (Reference 28), as well as field inspection. In order to supplement these data sources, plans from the Honokaa-Paahau (Reference 33) and Honokaa Park Development (Reference 34) were used.

NORTH KONA AREA

The locations for the major drainageways studied by detailed methods in North Kona were determined from topographic maps (Reference 10), field inspection, information from local residents at several public meetings and a helicopter survey of the damaged area just after the storm in February 1982. A total of seven drainageways were identified as having definite flow patterns and potential for causing the most damage.

SOUTH KONA AREA

The locations of the watercourses studied by detailed methods in South Kona were determined from the 5-foot and 10-foot contour internal maps (Reference 14), stereoscopic delineation from aerial photographs, field inspections and USGS topographic quadrangle maps. The contributing drainages areas were delineated and measured from the USGS 7.5 minute quadrangle maps (Reference 17).

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Insurance Rate Map (Exhibit 2).

The 10-, 50-, and 500-year floods were not completed for the following streams, therefore, only 100-year elevations are shown on the profiles:

Waiakea Tributaries No. 1,2, and 3
Palai Stream (Above Haihai Street)
Palai Stream Tributaries A through F
Four Mile Creek (shallow flooding area)
Four Mile Creek Tributary No. 3
Honokaa Drainages 1 through 3, and A through D.

Due to steepness of slopes and scale limitations, only the 100-year flood elevations are shown on the North Kona and South Kona Stream profiles.

For the entirety of the shoreline of Hawaii County, all of which was studied by detailed methods, tsunami wave elevations were determined utilizing a length of record of 138 years (1837-1975). A hybrid finite element numercial model was developed to supplement historical data in determining the ten largest tsunami elevations from 1837 to 1975. The finite element model provides an accurate, representative response of the Island to tsunami activity due to rapid bythymetric and/or wave height variations. The numercial model was adjusted and verified by comparing the numercial calculations with tide gage recordings of the 1960 and 1964 tsunamis. Tsunami elevations at a location 200 feet inland from the shoreline for Hawaii county were determined using the COE report prepared by the U.S. Army Waterways Experiment Station in conjunction with Japanese Tsunamis in Hawaii - A Preliminary Report by D. C. Cox (Reference 35 and 36).

Tsunami elevations, as the wave travels inland, and the maximum inundation limits were determined utilizing a study entitled Tsunami Inundation Prediction (Reference 37). Runup elevations and inundation limits are dependent upon initial tsunami elevations, ground elevation 200 feet inland, roughness factors (Manning's "n"), terrain slope, and Froude's Number (F=1 for non-bore; F=2 for bore information).

Approximate flooding in some portions for North Kona and South Kona areas was taken from the December 1984 North Kona Flood Plain Management study (Reference 2) and the July 1977 South Kona Flood Hazard report (Reference 3).

For the approximate analyses along Waikoloa Stream and Kamuela Stream No. 1, the COE HEC-2 step-backwater program (Reference 11) was used to establish the 100-year water-surface elevations. Backwater computations for Waikoloa Stream and Kamuela Stream No. 1 were based on cross section derived from topographical maps (Reference 28) and data from field surveys. Plans from the Waimea Road Improvements (Reference 38), the Kuhio Village Roads construction (Reference 39) and the Hawaii Belt road (Reference 40) were adopted for use in the study.

For the remaining approximate analyses, a computerized normal depth routine was implemented to establish the 100-year water-surface elevations. Cross section data for approximate study areas were derived directly from aeirial topographic survey maps, with channel roughness factors (Manning's "n") selected on the basis of field investigations (Reference 41).

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

All elevations are referenced to the National Geodetic Vertical Datum of 1929 (NGVD). Elevation reference marks used in this study

are shown on the maps; the descriptions of the marks used in this study are shown on the maps; the descriptions of the marks are presented in Elevation Reference Marks (Exhibit 3). Because many areas are relatively undeveloped, many elevation reference marks are located by traverse.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages state and local governments to adopt sound floodplain management programs. Therefore, each Flood Insurance Study provides 100-year flood elevations and delineations of the 100- and 500-year floodplain boundaries and 100-year floodway to assist communities in developing floodplain management measures.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1 percent annual chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2 percent annual chance (500-year) flood is employed to indicate additional areas of flood risk in the community. For each stream studied in detail, the 100- and 500-year floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated.

Information used in delineating flood boundaries for each stream studied by detailed methods is given below:

SOUTH KOHALA AREA

The flood boundaries for detailed study streams in the South Kohala area were delineated based on topographic maps furnished by the COE (Reference 15). Information on historic flooding was obtained from previous reports covering the study area (Reference 19, 42, and 43).

SOUTH HILO, KAU, AND HAMAKUA AREAS

The flood boundaries for streams studied in detail within these areas were delineated using COE topographic maps (Reference 15, 16, 18 and 28).

NORTH KONA AND SOUTH KONA AREAS

Flood boundaries for detailed streams were delineated from photogrammetric mapping used in the 1984 and 1977 SCS reports developed for the North Kona and South Kona areas (Reference 2, 3, 10, and 14).

HAWAII COUNTY COASTLINE

Coastal floodplain boundaries were taken from the 1982 Flood Insurance Study for Hawaii County (Reference 1). The portion of the coast inundated by the 100-year tsunami wave, was determined

utilizing tsunami wave elevations, runup elevations and known topographic characteristics and is based upon a depth of flooding by the incoming tsunami wave of 4.0 foot. The 100-year tsunami inundation boundaries were delineated using methods outlined in Tsunami Inundation Prediction (Reference 37).

The 100- and 500-year floodplain boundaries are shown on the Flood Insurance Rate Map (Exhibit 2). On this map, the 100-year floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A. AE, AH, AO, and VE); and the 500-year floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 100- and 500-year floodplain boundaries are close together, only the 100-year floodplain boundary has been shown Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

Approximate 100-year floodplain boundaries in portions of the North and South Kona areas were taken from the 1984 and 1977 SCS reports (References 2 and 3).

The approximate 100-year flood boundaries for Waikoloa Stream and Kamuela Stream No. 1 were delineated using topographic maps at a scale of 1:1200 and contour interval of 5 feet (Reference 28).

The 100-year floodplain for the remaining approximate flooding sources in the study area were taken directly from the 1982 Flood Insurance Study for Hawaii County (Reference 1).

For the streams studied by approximate methods, only the 100-year floodplain boundary is shown on the Flood Insurance Rate Map (Exhibit 2).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 100-year floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. To provide guidance for encroachment into these areas, a floodway is delineated for that part of the 100-year floodplain that conveys flow. Floodways were not computed for the following stream, due to their hazardous stream velocities:

Gulch 2 - Hapuna
Gulch 3 - Hapuna
Kamakoa Gulch
Gulch 4 - Puako
Auwaiakeakua Gulch
Waiakea Stream (downstream reach)
Ninole Gulch
Four Mile Creek Tributary No. 1

For these streams, the floodway boundaries are shown as that portion of the 100-year floodplain that conveys flow, and no cross section data are tabulated in the Floodways Data Table (Table 2).

Floodways are shown for Lanimaumau Stream and Alenaio Stream. At stream segments where hazardous velocities exist, the floodway boundaries as shown are the 100-year flood boundaries, and no cross section data are tabulated in the Floodway Data Table (Table 2).

No floodways have been computed for the following sources:

Waiakea Tributaries 1, 2, and 3
Palai Stream (Above Haihai Street)
Palai Streams A through F
Four Mile Creek (the upstream shallow flooding reach)
Four Mile Creek Tributaries 2 and 3
Honokaa Drainages 1, 2, and 3
Honokaa Drainages A through D
Detailed streams in the North Kona and South Kona areas

The floodways presented in this study were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated at selected cross sections (Table 2). In cases where the floodway and 100-year floodplain boundaries are either close together or collinear, only the floodway boundary has been shown.

The area between the floodway and 100-year floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood more than foot at any point. Typical relationships between

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE[3]
					(FEET NGVD)			
Four Mile Creek								
A	1415	150	2334	3.1	203.1	203.1	203.6	0.5
B	2610	140	815	2.3	203.2	203.2	204.2	1.0
C	3910	135	4427	4.3	246.1	246.1	247.1	1.0
D	5010	70	331	5.4	273.2	273.2	274.1	0.9
E	5870	350	363	5.0	276.9	276.9	277.0	0.1

[1] Feet from Kanoelehua Avenue.

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

FLOODWAY DATA

FOUR MILE CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE[3]
					(FEET NGVD)			
Alenaio Stream								
A	3480	884	4284	1.2	20.0	20.0	20.2	0.2
B	3700	611	2016	2.5	21.0	21.0	21.0	0.0
C	4070	750	1814	2.8	26.6	26.6	26.6	0.0
D	4300	545	1667	3.1	31.6	31.6	32.6	1.0
E	4640	165	1005	5.8	38.6	38.6	38.6	0.0
F	4985	67	517	11.3	52.1	52.1	52.1	0.0
G	5360	47	376	15.6	66.4	66.4	66.5	0.1
H	5795	114	627	9.3	84.3	84.3	84.3	0.0
I	6065	115	623	9.4	91.4	91.4	91.4	0.0
J	9885	132	650	9.0	249.4	249.4	249.5	0.1

[1] Feet Above Confluence With Waiola River.

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

FLOODWAY DATA

ALENAIO STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE[3]
					(FEET NGVD)			
Waiakea Stream								
A	7,650	95	510	7.0	182.8	182.8	183.8	1.0
B	8,700	88	323	11.1	239.6	239.6	239.6	0.0
C	14,350	65	277	11.9	421.7	421.7	421.7	0.0
D	14,750	58	267	12.3	430.3	430.3	430.3	0.0
E	15,400	78	297	11.1	443.1	443.1	443.1	0.0
F	16,100	65	402	8.2	461.4	461.4	462.2	0.8
G	16,400	166	422	7.8	464.8	464.8	465.1	0.3
H	16,800	55	527	6.2	470.8	470.8	470.8	0.0
I	17,600	72	385	8.5	503.3	503.3	503.4	0.1
J	18,600	80	299	11.0	538.9	538.9	538.9	0.0
K	20,700	80	234	14.0	599.1	599.1	599.2	0.1
L	21,500	94	372	8.8	619.9	619.9	619.9	0.0
M	21,900	228	493	6.7	625.4	625.4	626.1	0.7

[1] Feet Above Confluence With Waiakea Pond.

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

FLOODWAY DATA

WAIAKEA STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE[3]
					(FEET NGVD)			
Lanimaumau Stream								
A	-14,180	185	202	9.5	2628.2	2628.2	2628.2	0.0
B	-13,210	66	169	9.5	2653.8	2653.8	2654.2	0.4
C	-12,480	139	456	3.5	2659.7	2659.7	2660.7	1.0
D	-11,420	244	364	5.9	2682.9	2682.9	2682.9	0.0
E	-10,380	129	928	1.3	2692.9	2692.9	2692.9	0.0
F	- 8,510	53	121	7.4	2725.7	2725.7	2726.3	0.6
G	- 7,570	17	41	12.9	2736.8	2736.8	2736.8	0.0
H	- 5,570	133	59	2.5	2759.5	2759.5	2759.5	0.0
I	- 4,420	27	56	7.6	2776.7	2776.7	2776.9	0.2
J	- 2,510	40	129	8.9	2804.8	2804.8	2805.4	0.6
K	- 1,615	13	86	6.4	2818.7	2818.7	2819.1	0.4
L	- 290	21	69	8.0	2839.1	2839.1	2839.1	0.0
M	- 600	43	60	9.2	2854.8	2854.8	2854.8	0.0
N	3,575	20	70	10.7	3076.1	3076.1	3076.1	0.0

[1] Feet from Mamalahoa Highway

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

FLOODWAY DATA

LANIMAUMAU STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE[3]
					(FEET NGVD)			
Palai Stream								
A	1,150	234	1469	3.3	23.2	23.2	23.8	0.6
B	2,500	147	534	9.0	28.2	28.2	28.4	0.2
C	3,910	143	510	8.9	39.2	39.2	39.3	0.1
D	5,000	139	987	4.3	45.7	45.7	46.4	0.7
E	6,760	247	644	6.7	58.0	58.0	58.5	0.5
F	8,160	260	1385	2.9	69.8	69.8	70.2	0.4
G	9,560	98	457	8.8	79.2	79.2	79.3	0.1
H	10,800	166	1394	2.7	90.2	90.2	90.4	0.2
I	11,800	128	803	4.8	91.6	91.6	92.2	0.6
J	12,950	127	446	8.1	111.2	111.2	111.9	0.7

[1] Feet Above Confluence With Waiakea Pond.

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAWAII COUNTY, HAWAII

FLOODWAY DATA

PALAI STREAM

the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 3.

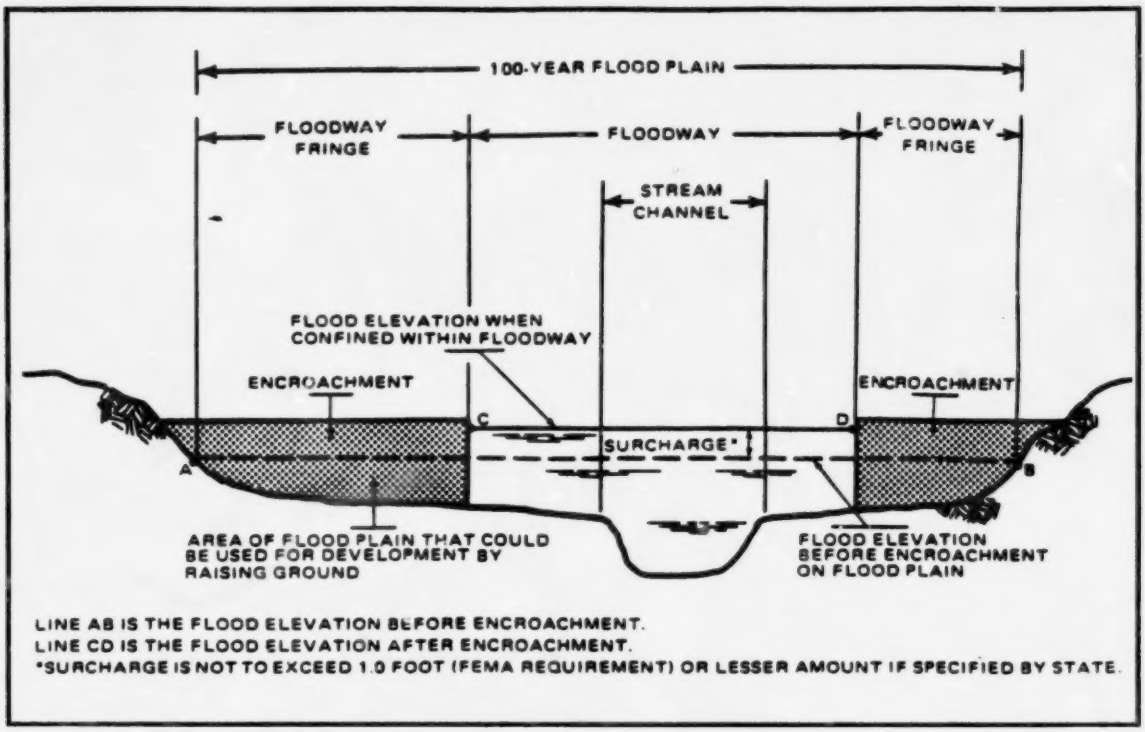
100-YEAR FLOOD PLAIN
FLOODWAY FRINGE
FLOODWAY
FLOODWAY FRINGE
STREAM CHANNEL
FLOOD ELEVATION WHEN CONFINED WITHIN FLOODWAY
ENCROACHMENT
ENCROACHMENT
C
D
SURCHARGE*
A
B
AREA OF FLOOD PLAIN THAT COULD BE USED FOR DEVELOPMENT BY RAISING GROUND
FLOOD ELEVATION BEFORE ENCROACHMENT ON FLOOD PLAIN
LINE AB IS THE FLOOD ELEVATION BEFORE ENCROACHMENT.
LINE CD IS THE FLOOD ELEVATION AFTER ENCROACHMENT.
*SURCHARGE IS NOT TO EXCEED 1.0 FOOT (FEMA REQUIREMENT) OR LESSER AMOUNT IF SPECIFIED BY STATE.

Figure 3. Floodway Schematic

The Coastal High Hazard Area consists of all areas identified by VE Zones. Special performance standards for construction in these Coastal High Hazard Areas are required by FEMA.

The inundation limits for the 100-year tsunami are based on existing conditions. Any modification or alteration to existing conditions may have a significant effect on the tsunami inundation limits. For example, any regrading or reduction of surface roughness in onshore area, such as that used by the removal of native vegetation, could increase the extent of inundation. Similarly, dredge and fill operations offshore could increase the extent of inundation due to the effects of coastal bathymetry on tsunami wave setup. On the other hand, existing or planned coastal features such as natural reefs, seawalls, groins, jetties, or beach stabilization projects may have a mitigating effect on tsunami inundation

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4.3 Tsunami Inundation Boundaries

Inundation limits from the 100-year tsunami were computed for most of the coastline of Hawaii County. The methodology employed in this computation is described in Section 4.1. The 100-year tsunami inundation zone is divided into two districts. Where the depth of water from the 100-year tsunami exceeds 4 feet, the area is identified as a VE Zone. the remainder of the area lying within the inunation limits of the 100-year tsunami has a depth of flooding of less than 4 feet and is identified as an AE Zone. All AE and VE Zones are identified on the Flood Insurance Rate Map except where cliff conditions exist or where the zones are too narrow to show, due to map scale limitations. In cases where the AE and VE Zones are too small to be shown separately, only the VE Zone was shown.

5.0 INSURANCE APPLICATION

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. These zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by detailed methods. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average

whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No base flood elevations or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The Flood Insurance Rate Map is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 100-year floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 100- and 500-year floodplains, floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway

7.0 OTHER STUDIES

A 1982 Flood Insurance Study has been prepared for hawaii County (Reference 1). This study revises and updated, and therefore supersedes, the previous Flood Insurance Study.

A COE report on the Palai Stream and Four Mile Creek drainage basins was completed in 1981 (Reference 31). Hydrology and hydrologic data from the report was incorporated into this study.computations.

The SCS published the North Kona Flood Plain Management Study in December 1984 (Reference 2) and the South Kona Flood Hazard Analyses report in July 1977 (Reference 3). Detailed and approximated flooding sources in the North Kona and South Kona areas were taken from these reports.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting the Natural and Technological Hazards Division, FEMA, Presidio of San Francisco, Building 105, San Francisco, California 94129.

9.0 BIBLIOGRAPHY AND REFERENCES

1. Federal Emergency Management Agency, Flood Insurance Study, Hawaii, County, Hawaii, May 3, 1982.

2. U.S. Department of Agriculture, Soil Conservation Service, North Kona Flood Plain Management Study, December 1984.

3. U.S. Department of Agriculture, Soil Conservation Service, South Kona Flood Hazard Analyses, July 1977.

4. U.S. Department of Commerce, Bureau of the Census, 1980, Census of Population, Number of Inhabitants, Hawaii, Washington, D.C., U.S. Government Printing Office, (Unpublished).

5. Water Resources Council, Bulletin 17, "Guidelines for Determining Flood Flow Frequency", Washington, D.C., March 1976.

6. U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.

7. U.S. Department of Agriculture, Soil Conservation Service, Computer Program for Project Formulation - Hydrology, Technical Release No. 20, May 1065.

8. U.S. Department of Agriculture, Soil Conservation Service, Soil Survey of Island of Hawaii, State of Hawaii, December 1973.

9. U.S. Department of Commerce, Rainfall-Frequency Atlas of the Hawaiian Islands, Weather Bureau Technical Paper NO. 43, 1962.

10. R. M. Towill Corp., Topographic Maps, Scale 1:4800, Contour Interval 5 and 10 feet, North Kona Area, 1977.

11. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-2 Water Surface Profiles, User Manual, Davis, California, October 1973.

12. U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 5, Hydraulics.

13. U.S. Department of Agriculture, Soil Conservation Service, WSP2 Computer Program, Technical Release No. 61, May 1976.

14. U.S. Department of Agriculture, Soil Conservation Service, Topographic Maps, Scale 1:4800, Contour Interval 10 Feet, South Kona Area, October 1976.

15. U.S. Army Corps of Engineers, Aerial Photogrammetric Maps, Scale 1:4,800, Contour Interval 10 Feet: Honolulu, Hawaii, January 1977.

16. U.S. Army Corps of Engineers, Aerial Photogrammetric Maps, Scale 1:2,400, Contour Interval 5 Feet: Honolulu, Hawaii January 1977.

17. U.S. Department of the Interior, Geological Survey, 7.5 Minute Series Topographic Maps, Scale 1:24,00, Contour Interval 20 Feet: Anaehoomalu, Hawaii, 1959, Hawi, Hawaii, 1957; HIlo, Hawaii 1963; Honauna, Hawaii, 1959; Honokaa, Hawaii, 1957; Honokane. Hawaii, 1957; Ka Lai, Hawaii, 1965; Kau Desert, Hawaii, 1963; Kauluoa Point, Hawaii, 1962; Kawaihe, Hawaii, 1956; Keaau Ranch, Hawaii. 1963; Keahole Point, Hawaii, 1959; Kealakekua, Hawaii, 1960;Keawanui Bay, Hawaii, 1957; Mahukona, Hawaii, 1957, Makalawena, Hawaii, 1959; Makaopuhi Crater, Hawaii, 1963; Manuka Bay, Hawaii, 1962; Milolii, Hawaii, 1962; Naalehu, Hawaii, 1962; Naliikakani Point, Hawaii, 1963; Pahala, hawaii, 1966; Papaikou, Hawaii, 1966; Pohue Bay, Hawaii, 1962; Punaluu, Hawii, 1966; Puu Hinai, Hawaii, 1956; Puu Hou, Hawaii, 1962.

18. U.S. Army Corps of engineers, Aerial Photogrammetric Maps, Scale 1:1,200, Contour Interval 5 Feet: Honolulu, Hawaii, January 1977.

19. U.S. Department of Agriculture, Soil Conservation Services, in cooperation with State of Hawaii, Mauna Kea Soil Conservation District, Watershed Work Plan, Puukapu Watershed, November 1961.

20. R. M. Towill Corporation, Kuhio Village, Increment II, Proposed Offsite Drainage Improvements, Exhibit B, Puukapu, Waimea, South Kohola, Hawaii, September 1977.

21. U.S. Army Corps of Engineers, Honolulu District, Waiola Stream and Tributaries Flood control Project, Hilo, Hawaii (As-Built Drawings 30/30), Hilo Hawaii, 1965.

22. Hawaii County, Hawaii, Department of Public Works, Lanikaula Street Extension, Waiakea, South Hilo, Hawaii, Hilo, Hawaii, 1967.

23. County of Hawaii, Department of Public Works, Bureau of Plans and Surveys, Hilo Storm Drainage, Waiakea Stream Improvements Between Golden Shower Tree Estates and Kawailani Street Bridge, Job No. P-2565, August 1983.

24. County of Hawaii, Department of Public Works, Bureau of Plans and Surveys, Hilo Storm Drainage, Waiakea Stream Improvements Between Golden Shower Tree Estates and Kawailani Street Bridge, Job P-2085, August 1976.

25. County of Hawaii, Department of Public Works, Bureau of Plans and Surveys, Hilo Storm Drainage, Waiakea Stream Improvements at Kupulau Road, Job P-2085, August 1976.

26. Imata and Associates, Inc., Lehua Heights Subdivision, Unit 1 and 2, Hilo, Hawaii.

27. Imata and Associates, Inc., Golden Shower Tree Estates Subdivision, Units 1 and 2, Hilo, Hawaii, December 1982.

28. U.S. Army Corps of engineers, Aerial Photogrammetric Maps, Scale 1:1,200, contour Interval 5 Feet: Honokaa, Hawaii, April 1984; Kamuela, Hawaii, April 1984; February 1977, Hilo Mauka, Hawaii, June 1982; Palai, Four-Mile Creek Area, August 1980.

29. Wilsho, Okamota, and Associates, Inc., Hilo Drainage and Flood Control, Hilo, Hawaii, january 1967.

30. Neighbor Island Consultants, Alenaio Stream Flood Control Improvements, Plan and Profile, Hilo, Hawaii, no date.

31. U.S. Army Corps of Engineers, Honolulu, District, Flood Plain Management Planning Assistance Report for Palai Stream and Four Mile Creek, Hilo, Hawaii, September 1981.

32. County of Hawaii, Department of Public Works, Bureau of Plans and Survey, Widening of Palai Street Bridges, Waiakea, Hilo Hawaii, June 1983.

33. State of Hawaii, Department of Transportation, Honokaa-Paauhau Road, Project No. S 238(1), Sheet No. 5589.4, 5589.5, & 5589.6, 1952.

34. County of Hawaii, Department of Public Works, Honokaa Park Development P-1929, Sheet C-2 and C-18, July 1974.

35. U.S. Army Corps of Engineers, Technical Report H-77-16, Tsunami Wave Elevation Frequency of Occurrence for the Hawaiian Islands by J. R. Houston, R. D. Carver, and D. G. Markle, Vicksburg, Mississippi, Waterways Experiment Station, August 1977.

36. D. C. Cox, Japanese Tsunamis in Hawaii - A Preliminary Report, Environmental Center, University of Hawaii, January 1980.

37. C. L. Bretschneider and P. G. Wybro, Tsunami Inundation Prediction, presented at 15th International Conference on Coastal Engineering, Honolulu, Hawaii, July 1976.

38. County of Hawaii, Department of Public Works, Waimea Road Improvements, Waimea, South Kohala, Hawaii, Job No. P-1596, June 1969.

39. Kuhio Village Roads Construction Plans, Hawaiian Homes Commission.

40. State of Hawaii, Department of Transportation, Hawaii Belt Road, Project No. SDR 3(7), Sheet No. 5590.4 & 5590.5, 1952.

41. U.S. Department of the Interior, Geological Survey, Water-Supply Paper 1849, Roughness Characteristics of Natural Channels by Harry H. Barnes, Jr., Washington, D.C., 1967.

42. U.S. Army Corps of Engineers, Honolulu District, in cooperation with the State of Hawaii, Department of Land and Natural Resources, Report No. 37, Flood Hazard Information, Island of Hawaii, Honolulu, Hawaii, September 1970.

43. U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the U.S. Army Corps of Engineers, Honolulu District, and the Sate of Hawaii, Hawaii Map FP-2, Hilo Flood Hazard Area, Hilo, Hawaii, March 1970.